



Leveraging Public Data to Reconstruct the Cost History of Planetary Exploration

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Motivations

- Publicly-reported mission costs are **inconsistent and lack detail**
- **Comparisons are difficult** between missions and over time
- A problem for both public education and advocates:
 - Press kit numbers are what gets reported!
 - How much “should” a mission cost?
 - How to interpret the total cost—is a \$1B mission “expensive” or “a good deal”?
 - How much is a mission in the context of all planetary spending? Or all of NASA spending?
 - How much of a mission cost are development, launch, and operations?

MSL Curiosity Press Kit:

Cost: \$2.5 billion, including \$1.8 billion for spacecraft development and science investigations and additional amounts for launch and operations.

Perseverance Press Kit:

NASA has invested approximately \$2.4 billion to build and launch the Mars 2020 Perseverance mission. The estimate to land and operate the rover during its prime mission is approximately \$300 million.

Voyager Press Kit:

Estimated cost of the Voyager project, exclusive of launch vehicles, tracking and data acquisition and flight support activities is \$320 million.

Juno Press Kit:

The Juno mission investment is approximately \$1.1 billion in total. This cost includes spacecraft development, science instruments, launch services, mission operations, science processing and relay support for 74 months.

An artistic illustration of space exploration. In the foreground, a yellow spacecraft with a large blue parabolic dish antenna and various instruments is shown. In the background, a large planet with rings (resembling Saturn) is visible. Further back, a solar system with a central yellow star and several planets (including a large orange one) is depicted with elliptical orbits. A yellow arrow points towards the left. An orange horizontal bar is located in the upper right area.

What does it
cost to explore
the planets?

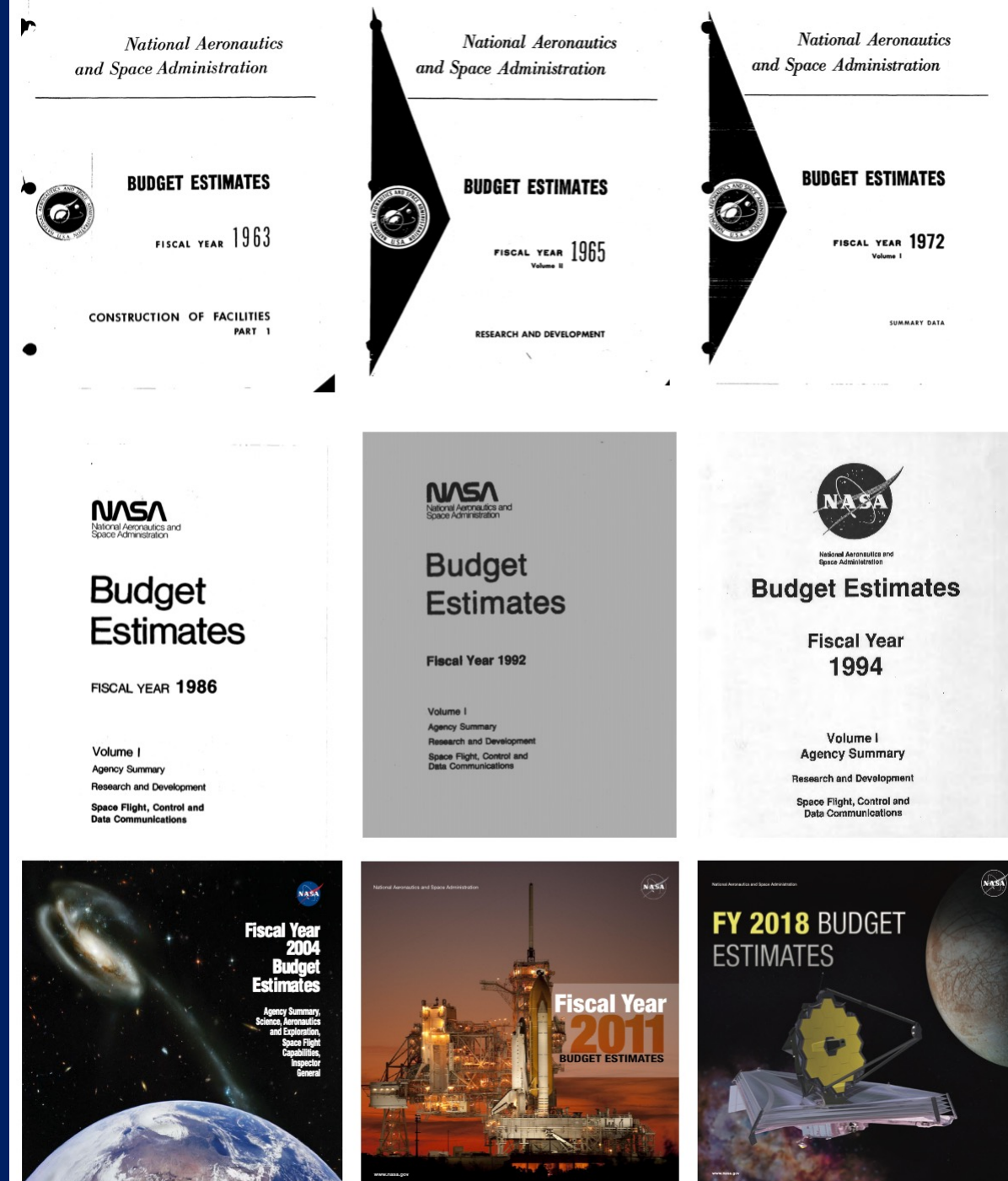
Project Goals

- Compile a **complete record of mission and program costs** for NASA's robotic planetary program using public data.
- Useful for public and public policy discourse:
 - Normalized to include accounting changes
 - Include all mission costs: development, launch, and all operations
 - Inflation-adjusted values
 - Provide costs by year
- Easily and freely accessible



Method

- Primary source: NASA budget estimates provided by NASA HQ History Office
- Used “actual” reported obligations
- Augmented by a variety of secondary sources, in order of preference:
 - Official NASA statements (press releases, public briefings)
 - Projected values in PBRs
 - Reporting from high-quality news agencies
- Normalizations (“gap fill” strategy):
 - Include all LV costs, except STS
 - Removed Deep Space Network overhead
 - Restore “gaps” of mission funding (i.e. correct for temporary accounting changes)



Results

- Worked pretty well!
 - Reconstructed a reasonable data set from 1960 onward
- Google Sheet as prime source
 - <https://www.planetary.org/space-policy/planetary-exploration-budget-dataset>
 - versioned, exportable to popular formats (xlsx, csv, open office)
- Inflation adjustments
 - NNSI for R&D
 - Employment Cost Index for operations after 2001

[illegible]

What it contains

- **Requested AND obligated amounts** for NASA's robotic planetary program for each fiscal year since 1961
- **Mission tabs:**
 - annual obligations for nearly every major planetary science mission
 - includes development, launch, and operations
- **Summary tables:**
 - Total planetary program request and actual per year since 1959, with congressionally-enacted amounts since 2008
 - Spending by prime destination (Venus, Mars, Outer Planets, etc)
 - Timeline entries of every mission, with LV type and cost
 - "Decadal period" summaries

[illegible]

MSL Curiosity mission tab

Official LCC	Fiscal Year	Formulation	Implementation	Launch Services	Operations	Total Cost	Total Cost (inflation adj)	Notes						
\$2,476	2002	\$5.7				\$5.7	\$8.5	Finall LCC and other useful data in the NASA OIG report: https://oig.nasa.gov/docs/IG-11-019.pdf						
	2003	\$60.6				\$60.6	\$88.5	Began formulation: September 2003						
	2004	\$118.1				\$118.1	\$166.6	Mission Concept Review: Oct 2003.						
	2005	\$117.5				\$117.5	\$160.9							
	2006	\$213.6	\$37.4			\$251.0	\$333.1	KDP-C: August 2006. Original LCC: \$1.8 billion. Note: small adjustment to match final Formulation amount, slightly higher.						
	2007		\$416.8			\$416.8	\$532.7	CDR: June 2007						
	2008		\$545.0			\$545.0	\$672.5							
	2009		\$229.3			\$229.3	\$277.7	Project Rebaseline: 23 Feb 2009. Original launch date Sept 2009.						
	2010		\$258.4			\$258.4	\$308.8							
	2011		\$242.9			\$242.9	\$285.7							
	2012		\$174.0			\$174.0	\$202.4	Launch: Nov 26 2011. Landing Aug 2012.						
	2013				\$63.8	\$63.8	\$76.8							
	2014				\$69.6	\$69.6	\$82.2	Prime mission end: Summer 2014						
	2015				\$63.5	\$63.5	\$73.5							
	2016				\$50.3	\$50.3	\$57.0							
	2017				\$56.2	\$56.2	\$62.4							
	2018				\$51.4	\$51.4	\$55.7							
	2019				\$51.1	\$51.1	\$53.9							
	2020				\$50.0	\$50.0	\$50.0							
	2021				\$40.0	\$40.0	\$40.0							
	2022													
	2023													
	2024													
	2025													
Totals		\$515.5	\$1,903.8	\$194.7	\$495.9	\$2,915.2	\$3,588.8	Launch cost estimate from: https://www.nasa.gov/centers/kennedy/news/releases/2006/release-20060602d.html						
		21%	79%		17%			% dev spent on formulation vs. implementation. % TOTAL on operations						

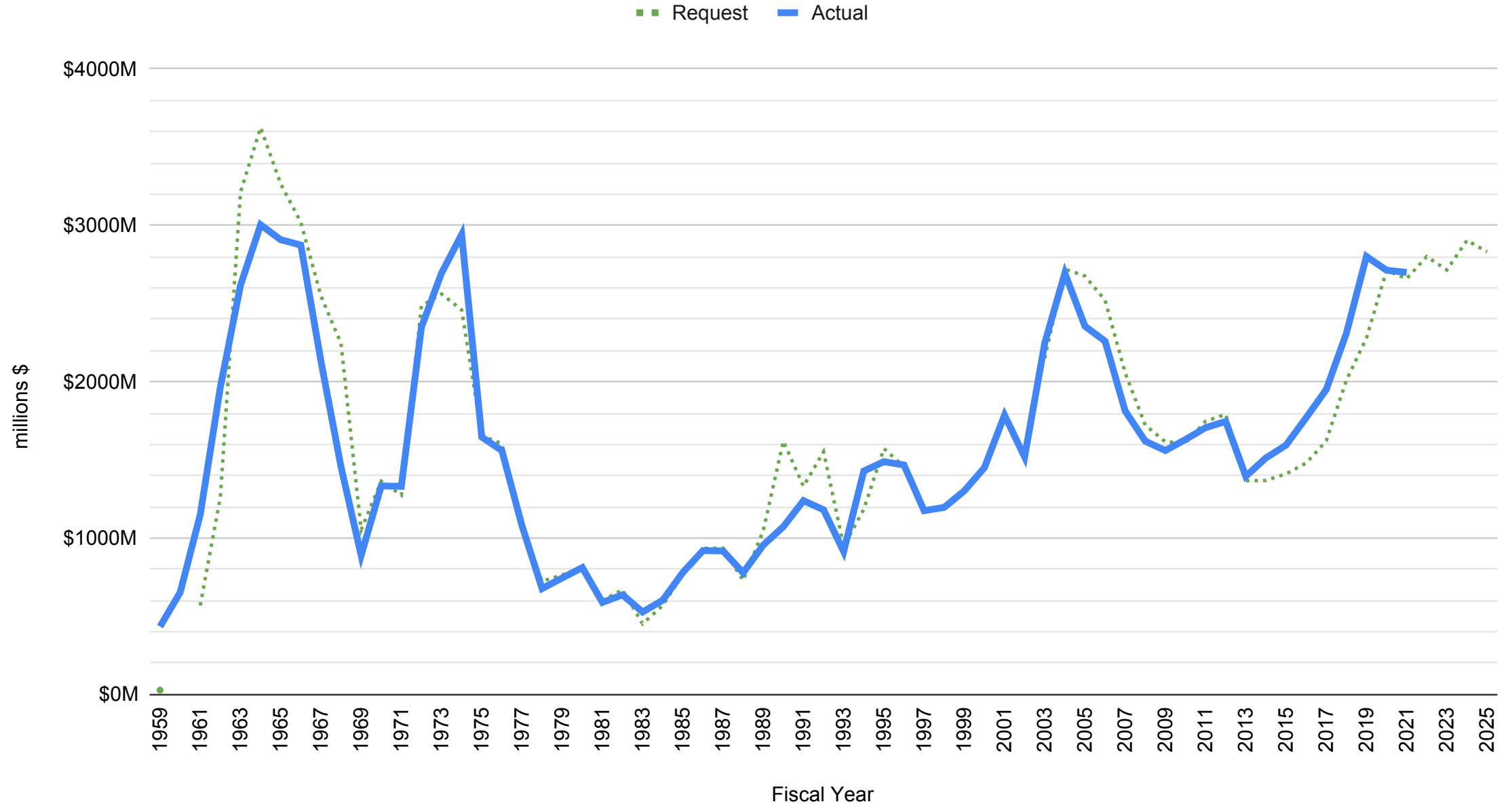
Example of a Fiscal Year tab, FY 1987

	Request	Enacted	Actual	Notes				
Research & Analysis	\$63.5		\$69.5	<i>Using "amended" FY87 budget estimates</i>				
Planetary supporting R&T	\$47.4		\$46.1					
Advanced Programs	\$10.1		\$16.6					
Mars Data Analysis	\$2.9		\$2.9					
Halley's comet investigations	\$3.1		\$4.0					
Galileo	\$77.0		\$71.2					
Mars Observer	\$62.9		\$35.8					
Magellan	\$69.7		\$105.3					
Ulysses	\$24.0		\$10.3					
Mission Operations & Data Analysis	\$77.2		\$75.1					
Ulysses	\$0.3							
Pioneer Programs	\$8.3		\$8.3					
Voyager/Neptune mission (Voy 2)	\$30.3		\$26.1					
Voyager Extended Mission (Voy 1)	\$4.8		\$2.8					
Flight Support	\$33.5		\$37.9					
STS Operations	\$66.3		\$23.6	<i>STS costs included here for reference but NOT included in program totals</i>				
Mars Observer	\$9.1		\$0.0					
Galileo	\$22.0		\$11.8					
Magellan	\$22.0		\$11.8					
Ulysses	\$13.2		\$0.0					
Total	\$374.3		\$367.2					

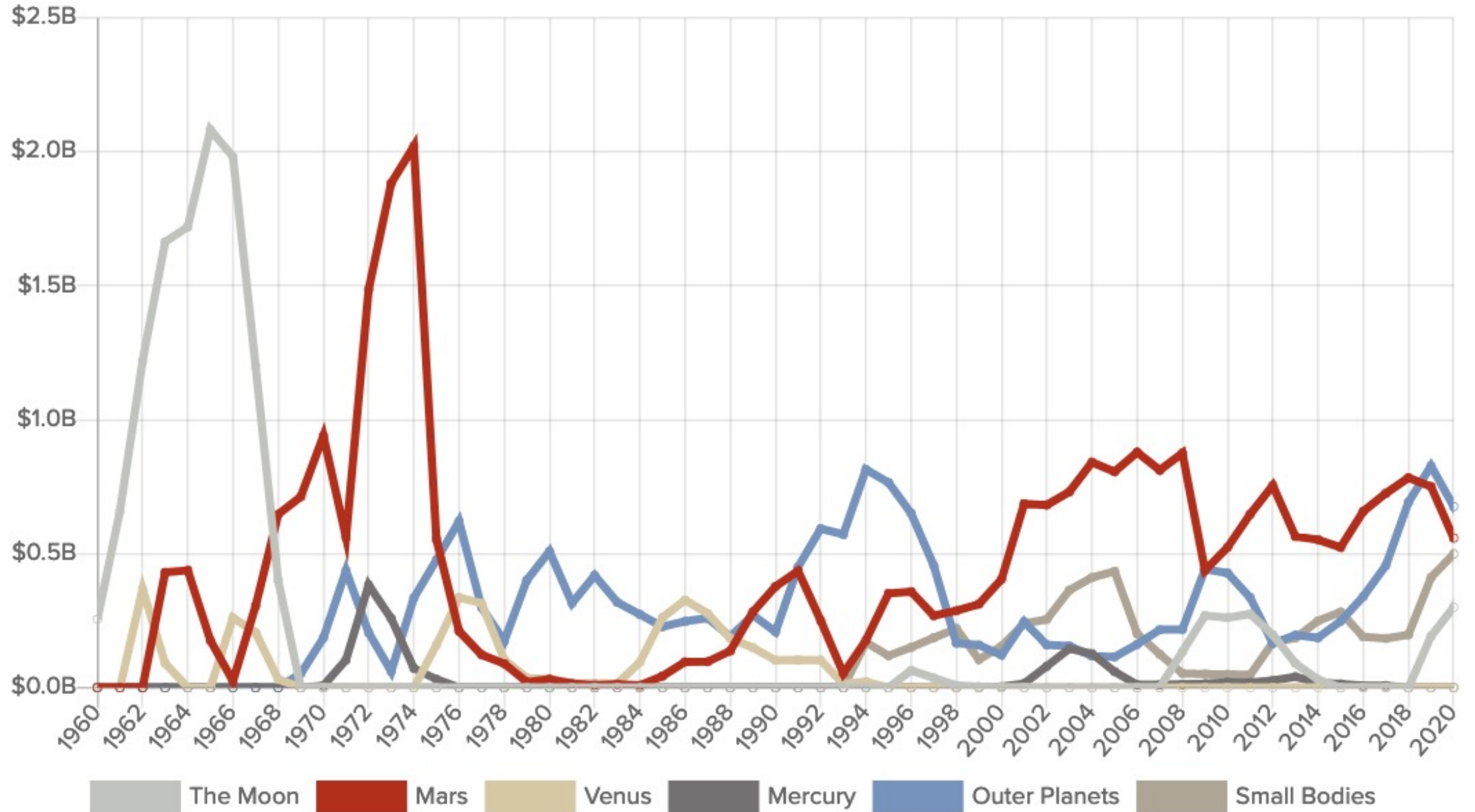
Summary table example: spending over “Decadal Survey-equivalent” periods

	Decadal Survey Equivalent Periods (2020 \$)							
Destination	1960 - 1962	1963 - 1972	1973 - 1982*	1983 - 1992	1993 - 2002	2003 - 2012	2013 - 2022	Total
Mercury	\$0	\$494	\$361	\$0	\$97	\$445	\$87	\$1,484
Venus	\$367	\$588	\$1,107	\$1,614	\$35	\$0	\$0	\$3,712
The Moon	\$2,133	\$9,047	\$0	\$0	\$111	\$1,137	\$1,581	\$14,010
Mars	\$0	\$5,717	\$5,017	\$1,738	\$3,578	\$7,307	\$6,252	\$29,608
Small Bodies	\$0	\$0	\$0	\$0	\$1,597	\$1,903	\$2,808	\$6,308
Outer Planets	\$0	\$880	\$3,746	\$3,038	\$4,109	\$2,352	\$5,208	\$19,333
Research/Overhead/Other	\$1,270	\$4,170	\$3,535	\$2,583	\$4,200	\$6,489	\$5,570	\$27,816
Program	1960 - 1962	1963 - 1972	1973 - 1982	1983 - 1992	1993 - 2002	2003 - 2012	2013 - 2022	Total
Ranger	\$1,596	\$1,308	\$0	\$0	\$0	\$0	\$0	\$2,904
Surveyor	\$537	\$5,648	\$0	\$0	\$0	\$0	\$0	\$1,162
Lunar Orbiter	\$0	\$2,091	\$0	\$0	\$0	\$0	\$0	\$2,091
Pioneer	\$0	\$1,664	\$1,659	\$187	\$38	\$0	\$0	\$3,549
Mariner	\$1,278	\$4,935	\$410	\$0	\$0	\$0	\$0	\$6,120
Discovery	\$0	\$0	\$0	\$0	\$2,077	\$2,371	\$3,398	\$7,847
Mars Surveyor/Exploration Program	\$0	\$0	\$0	\$0	\$3,041	\$7,231	\$5,428	\$15,700
New Frontiers	\$0	\$0	\$0	\$0	\$0	\$2,202	\$1,982	\$4,184
Total Planetary Program	\$3,770	\$20,896	\$13,765	\$8,973	\$13,728	\$19,633	\$21,506	\$102,320
			<i>*includes 1976 TQ</i>					

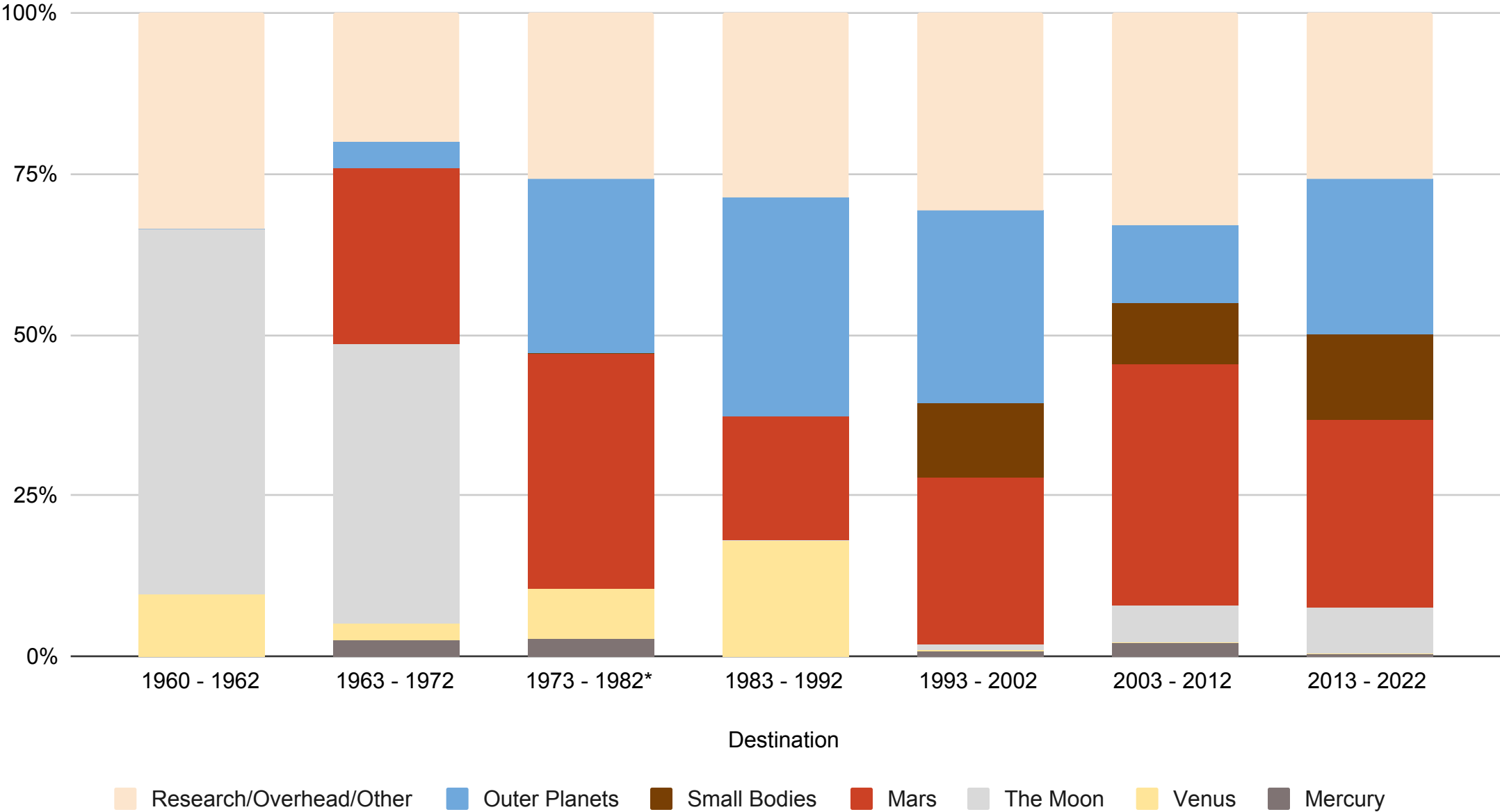
NASA's Robotic Planetary Program Totals (inflation adj)



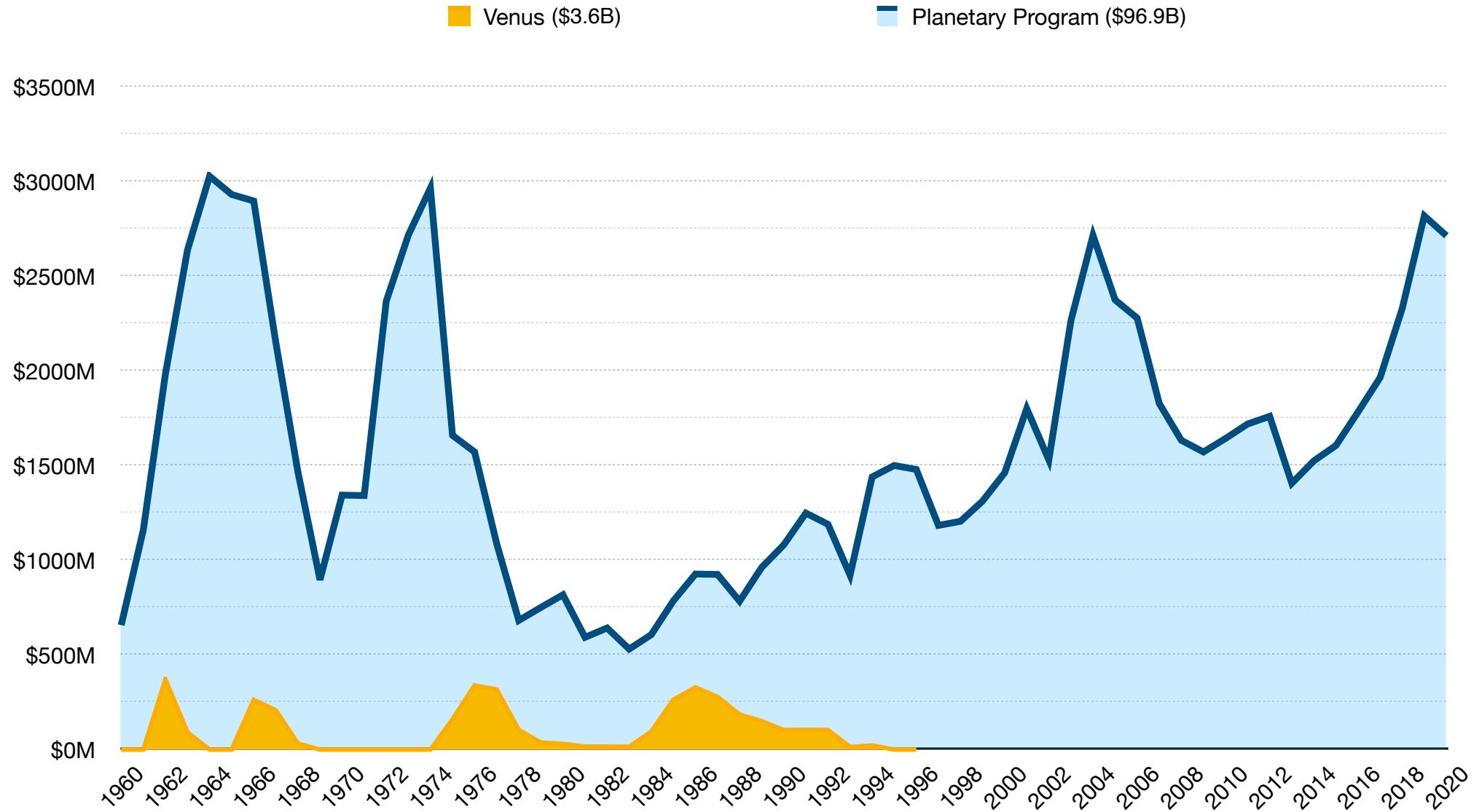
NASA Planetary spending by prime destination (inflation adj)



Spending by destination, by decadal period



NASA Venus Spending vs Planetary Program (inflation adj)

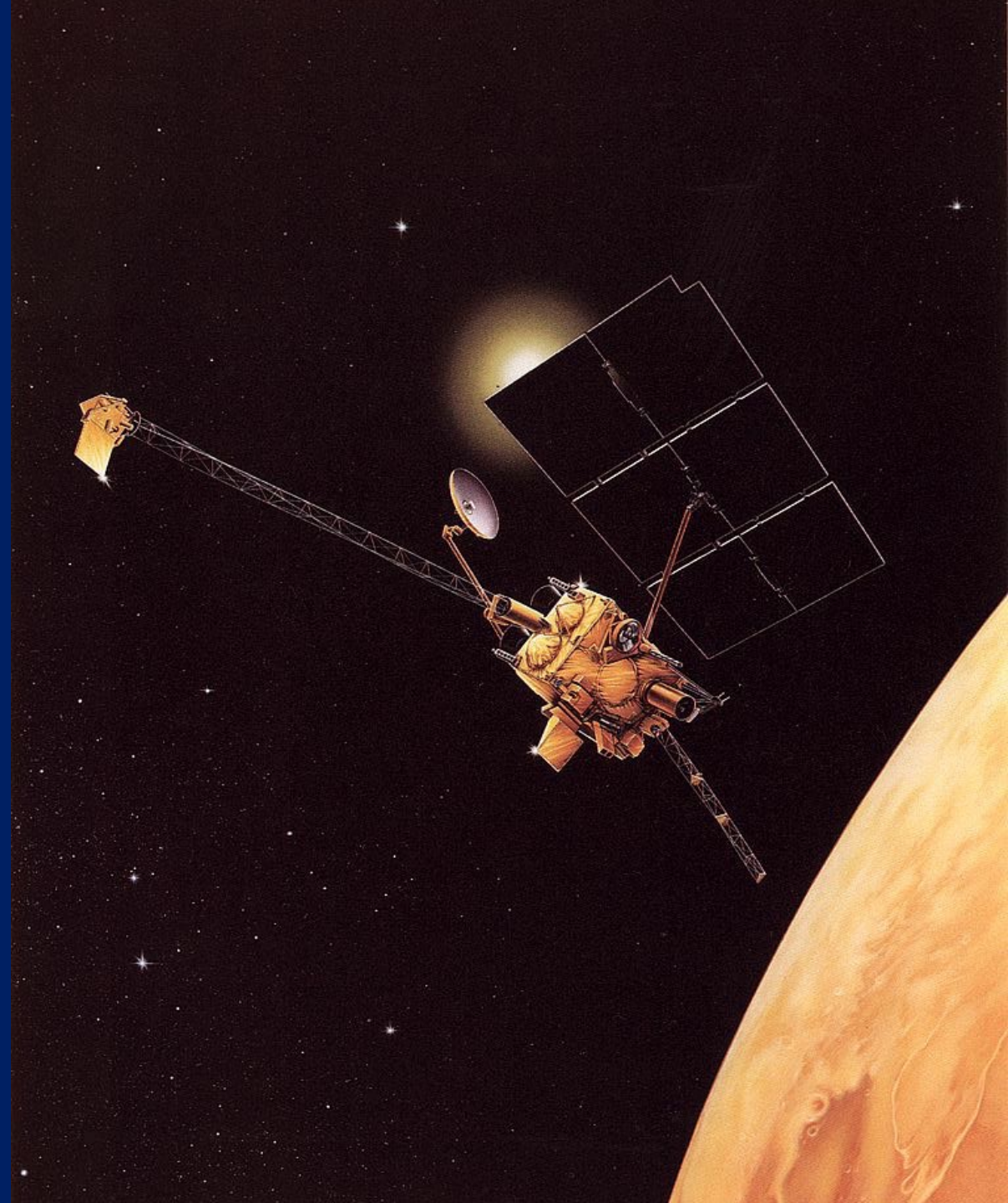


Launch Vehicle Costs for Planetary Missions (inflation adj)



Caveats

- Only as good as the reporting in budget estimates
- Obligations don't track outlays, and don't track contract revisions/alterations
- Certain eras have more detail than others
 - From FYs 1998 – 2003 planetary programs grouped with all space sciences,
 - 2004 – 2012 operating costs grouped in single account
 - LV costs during the 1960s are hard to tie to specific missions in a program series
 - 1959 – 1960 is what you'd expect
- No normalization possible for full-cost accounting change in FY2004
- Data is granular to the *fiscal year*



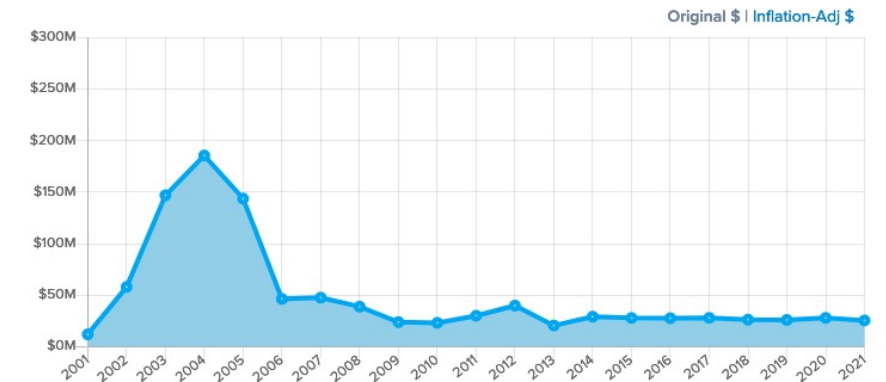
Outcome

- Data integrated throughout planetary.org and Wikipedia.
- Immediate and ongoing interest by media organizations, academia, and industry in the dataset and related products.
- Public budget data is relatively robust if you put in the time to compile it! Very transparent.
- Cost reporting from non-NASA entities pale in comparison.

Cost of the Mars Reconnaissance Orbiter

The Mars Reconnaissance Orbiter (MRO) cost \$716.6 million, of which \$416.6 million was for spacecraft development, \$90 million was for its launch, and \$210 million was for 5 years of operations during its primary mission. After beginning its extended mission in 2011, MRO's annual operations costs are, on average, \$31 million per year, when adjusted for inflation.

During its development and primary mission from 2001 to 2010, MRO accounted for 0.0028% of all spending by the United States.



Mars Reconnaissance Orbiter costs per fiscal year The project began formulation in 2001 and entered the implementation (build) phase in 2003. The orbiter launched in August 2005 and entered Mars orbit in September of 2006, where it has been in operation ever since. Source: *Planetary Science Budget Dataset*, compiled by Casey Dreier for The Planetary Society (accessible on [Google Sheets](#) or downloadable as an Excel file).

Development	\$416.6 million
Launch Vehicle (Atlas V 401)	\$90 million
Prime Mission Operations (5 years)	\$210 million
Total	\$716.6 million
Extended mission operations (avg)	\$31.6 million / year (inflation adjusted)

Feedback Welcome

- How can these data be better...
 - Interpreted?
 - Improved?
 - Presented?
- What other caveats should be included or accounted for?
- What other data sources should be considered or requested?

Acknowledgements

- Jason Callahan for top-line Planetary program levels for FYs 1998 – 2001 “Budgeting for Exploration: History and Political Economy in Space Science 1959-2010” Presented at the AAS 45th Meeting of the Division for Planetary Sciences, Denver, Colorado. October 7, 2013.
- NASA HQ History Office for digitizing and providing 50 years of NASA Budget Estimates.
- Special thank you to Planetary Society member/volunteer Shannon Bertolino for data validation.

THE **PLANETARY** SOCIETY

Planetary Exploration Budget Dataset:

<https://www.planetary.org/space-policy/planetary-exploration-budget-dataset>

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